IMPACT OF BIOCHAR ON ORGANIC AND INORGANIC ENVIRONMENTAL POLLUTANTS AND ITS MECHANISM: A REVIEW

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Anthropogenic activities have led to an increase the use and extraction of organic and inorganic pollutants. Pollutants cannot be easily accumulated and hence degraded in the environment, having the ability to pollute the food chain. This pollution threatens for human health, plant survival and soil quality. The remediation of organic and inorganic pollutants deserves consideration, but it is impaired by the charge of these processes. Biochar addition into soils by natural processes (bush burning, forest fires) or application to soil as agriculture, carbon storage, remediation and waste management has a significant amount of regulatory attention and scientific approach. Biochar effects on soil properties enhance microbial activity and increase adsorption of organic and inorganic complexes, but all these characteristics strongly depends on the production process of biochar from various feed stocks. This review considers various feedstocks sources, biochar production process and interactions of biochar with soil biota. Moreover, this review considers the interactions between biochar and other anthropogenic inorganic pollutants (heavy metals) and organic contaminants, such as PAHs, pesticides, which often contaminate the soil environment to large extent. It is oftenly considered applying biochar in remediation technologies in addition to other perception areas so far to be explored.
Keywords: Biochar, heavy metals, pesticides, Hydrocarbons, mechanism.

INTRODUCTION

The organic and inorganic contaminants cause the environment pollution by the means of anthropogenic and natural events such as industrial processes, extraction of minerals, effluents disposal activities, poor waste management, illegal dumping of waste material, excess use of chemical fertilizers and leakage of underground petroleum storage tanks (USEPA, 2010). However, the constant exploitation and development of organic (hydrocarbon) and inorganic resources, unwise use of agrochemicals as well as enhancement in population cause the dislocation and introduction of pollutants to the soil environment (Chen *et al.,* 2007). Heavy metal pollution has a tremendous effect in soil pollution due to excess use of heavy metals in industries and technically advanced condition. In contrast to organic substance heavy metals are non bio-degradable and hence easily accumulate in the environment. While heavy metal in the soil environment has an effective background history due to weathering of rocks parent material and volcanic activities. On the other hand, anthropogenic activities such as smelting and mining from industries, frequent use of pesticides, phosphate fertilizers and other waste products like sludge have great contribution of high level of metal accumulation in soil environment.

The use of industrial effluents having organic and inorganic compounds co-exists in soil environment. Soil characteristics such as pH, CEC, water holding capacity etc also show negative response on contaminated soil because of the eminent concentrations are prone to soluble, bioavailable and mobile fractions in soil. Beside this other water-soluble fractions of trace metals and as in soils are the most ecologically relevant because of it is more readily mobile and bioavailable within the environment causing bad impact (Mench *et al.,* 2009). Pollutants which come from spills, leaks and other releases of petroleum hydrocarbons can impact higher concentration of soil spread pollution representing a major environmental concern with serious consequences that has been also one of public health concerns worldwide over the recent decades (Lu *et al.,* 2010).

Moreover, pesticides are also biologically active molecules which can potentially put forward harmful effects to non-target organisms within the soil. Pesticides effects on the soil microbiota and its implications to different soil processes are crucial to the pesticide registration process. However some other pesticides shown a range of short-term impacts on soil microbial communities, including reduction of biomass, and altered community composition and functioning as well as evidence of effects on the long term functioning and health of soil has not been shown clearly (Bune- mann *et al.,* 2006).

From following study it was cleared that this loss is typically linked with a decline in soil quality, agronomic potential reduction and also cause of loss in ecosystem service provision which lead to cause SOM losses that play important role in exacerbating global climate change. Consequently, it is necessary that for preservation naturaly or anthropogenically, there are some engineered solutions are required and also promoting the existing organic and inorganic carbon (C) storage in soil (Lehmann, 2007; Manning, 2008).

Therefore, an appropriate method is used to mitigate the harmful pollutants by reducing their mobility by the application of biochar as a geosorbent to contaminated soils. Soil pollution is caused due to the excessive use of organic and inorganic contaminants; hence this review provides an important knowledge for the reclamation of contaminated soil by the application of biochar. More specifically the aims of this review is to (i) consider the fate and behaviour of heavy metal and their interaction with biochar, (ii) observe biochar manufacturing properties and interaction with heavy metals; (iii) suggest the application of biochar in increasing the reduction in mobility and bioavailability and adsorption of inorganic and organic pollutants.

***Sources of heavy metal pollution*:** Emission of harmful substance from vehicles and industries are emitted, deposited and accumulated daily on roads, pavements and adjoining soil. Anthropogenic activities like industrial activities, devastation, construction and other natural sources such as transport of long and short range suspended soil particles cause pollution. These waste materials deposited on streets and roads called rood, street deposited sediments. High concentration of heavy metals originates through anthropogenic fraction from vehicle brakes linings, fuel combustion and tires of vehicle (San-Miguel *et al.,* 2002) and also from metal smelting, municipal and solid waste material burning.

In arid and semi arid regions wastewater has been used for agriculture irrigation due to shortage of clean and fresh water. On the other hand, one of the astonishing side effects, larger areas of soils were polluted by heavy metals like cadmium (Cd) because of the ordinary practices to release of large quantity of untreated wastewater or after minimal preface treatments (Sun *et al.,* 2009). Heavy metals like chromium cause pollution in global and marine environment by arbitrary dispose of waste water and other effluents from different industries including leather tanning, pulp production, electroplating, timber treatment and oil refining (Zhitkovich 2011).

***Effect of pollutants on Soil environment (rhizosphere)*:** Microbial properties of soil are harmfully affected by soil heavy metal pollution (Yang *et al.,* 2012) and so also taxonomic characteristics and efficient diversity of soil effected (Vacca *et al.,* 2012). Pollution through heavy metal in soil poses a hazardous effect on environment and for human

health (Roy and McDonald, 2014) as some of these elements are essential for living organisms and some are harmful. Even that essential elements when cross over their permissible limits can cause serious threats as entered into metabolism system of living organisms. Kabata- Pendias and Pendias (2001) provides a list of information about toxic effect of heavy metals on human being and plant mechanism involved. However, a review of heavy metal effects severity on human health should be provided by Ali *et al.* (2013).

Presence of chromium Cr (VI) in water even in minute concentration has highly toxic effect (Owlad *et al.,* 2009). The maximum thresh hold level of total chromium in ground water and waste water is 2 mg L^{-1}, while for Cr(VI) is 0.05 mg L^{-1} (Park *et al.,* 2004). Pollution is not only caused in soil ecosystem but in agriculture production and also a severe threat for well being of human being. Approximately it is estimated that near about 3.5 million locations are potentially contaminated through industrial mining sites, energy generated plants, landfills and also from agriculture land (Petruzzelli, 2012).

The effective use of pesticides on soil can cause toxic effect on non target microbes. Some toxic pesticides have short term effect on soil microbial population, reduce microbial biomass, functioning and changing microbial community composition, although there is no long term effect shown on microbes function and soil health (Bunemann *et al.,*2006). Pesticides have direct effect on biodegradation rate of soil and toxic effect for target and non-target soil organisms, due to its bioavailability in soil environment (Whitacre, 2010).

***Role of Biochar*:** Biochar is product obtained in the absence of oxygen through thermal decomposition of biomass by the pyrolysis process (Chen *et al.,* 2010). Biochar is internationally famous due to its two important reasons (a) used as a amendments for enhancing crop yield and improve different soil properties, (b) biochar has a carbon storing pool in soil for carbon sequestering and have a potential abatement for green house emission of CO_2 (Uzoma *et al.,* 2011). Now in these days, climate change issues are raising and for this biochar are used as a solution (Kookana, 2010). Biochar application into soil can enhance cation exchange capacity (CEC) and soil pH. Sorption capacity of soil should be improved by addition of biochar.

Biochar application is important for heavy metal fate and behavior in soil. Nutrient efficiency is also improved in the soil by the application of biochar. Therefore application of biochar has a potential to promoting the plant cover establishment and phytostabilization techniques for remediation of contaminated soil (Beesley *et al.,* 2011). Biochar have a potential benefit for improving the biological properties of soil. (Paz-Ferreiro *et al.,* 2014) article has a more focused scope on the combination of phytoremediation and biochar with respect to environmental pollutants remediation. Moreover, in the recent years there have been an increasing

number of articles devoted to understanding the interaction between heavy metals, vegetation and biochar.

Biochar is used as a mitigating agent for climate change and enhancing soil fertility by improving the physical and chemical properties of soil. There is little bit attention given to the potentially toxic element present in the biochar. The most at tentative consideration is poly cyclic hydrocarbons, other metals and metalloids elements.

Mechanism of interaction between biochar and heavy metals: Biochar properties depend on several factors including various types of feed stocks, its particle size and different pyrolysis temperature. Biochar is considered as one of the most suitable material for remediation of heavy metals than others. Therefore, biochar characteristics should also be kept in mind by researcher along with soil properties while using it as a remediating agent. The ability of biochar to immobilize the heavy metals can be improved by key properties like ash contents, surface area, pH and organic carbon contents (Lima et *al.,* 2014).

Biochar interaction with heavy metals reduced their leaching ability and act on bioavailable fraction. Surface area is the one of the important property of biochar, which implies on that it have more ability to adsorb complex metal on surface. Sorption of heavy metals on surface of biochar can be demonstrated by scanning of electron microscopy (Lu *et al.,* 2012). Sorption of complex metal can be possible due to the prescence of different functional groups in biochar, by the exchange of various associated cations like Ca^{+2} and Mg^{+2} on biochar surface with heavy metals (Lu *et al.,* 2012) and other macro elements such as K^+, Na^+ and S also exchange complex heavy metals bound with them (Uchimiya *et al.,* 2011).

The positive role of oxygen functional groups presents on biochar surface serve for stabilization of specific heavy metals like Pb^{+2} and Cu^{+2}. Sorption of copper heavy metal through biochar functional groups or due to presence of Ca^{+2} and Mg^{+2} ions in biochar, or due to its properties like superficial charge density and pore size diameter of biochar. Heavy metals sorption mainly depends on soil type and various important cations on biochar surface, or presence of few more compounds like carbonates and phosphate used for adsorption (Park *et al.,* 2013). These compounds made their precipitates with metals pollutants. Alkaline nature of biochar is responsible for sorption of available heavy metal, because biochar have high pH by giving high pyrolysis temperature so it made precipitate of metals ions (Wu *et al.,* 2012). Biochar may help to reduce mobility of complex metals by changing their redox potential (Choppala *et al.,* 2012).
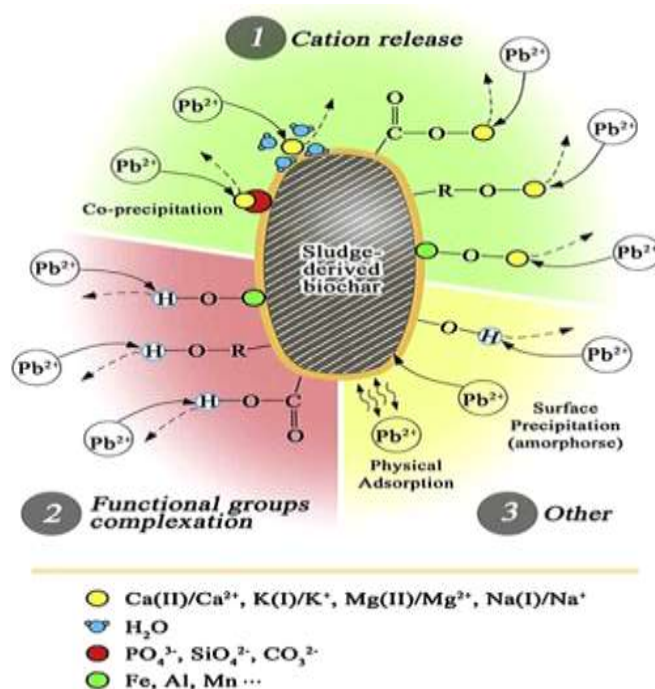

Figure 1: **Conceptual illustration of the possible mechanisms of Pb adsorption on biochar (from Lu *et al.,* 2012)**

Effect of biochar on heavy metal mobility: Heavy metal mobility can be reduced in contaminated soil by the application of biochar, which could minimize the risk of heavy metals through plant uptake. Biochar derived from bamboo waste material used for the sorption of heavy metals like Ni, Cu, Cr and Hg from soil and water and Cd from contaminated soil (Cheng *et al.,* 2006). Biochar prepared at low temperature 200 ^{0}C from dairy manure having higher soluble phosphate concentration is more effective for sorption of heavy metal like Pb as compared to biochar prepared at 300 ^{0}C temperature (Cao *et al.,* 2009). Biochar amendment has a great influence on heavy metal mobility in soil, reduce uptake, accumulation and translocation from root to shoot of plants with the help of iron plaque (Zheng *et al.,* 2012).

Biochar increased soil pH, having oxygen functional groups and different phosphrous levels which can reduce the heavy metals mobility in soil environment (Uchimiya *et al.,* 2012). The impacts of wheat straw derived biochar addition in soil to serve reduce mobility of heavy metals like Cd concentration resulted in decreased Cd in rice shoot and grain. (Cui *et al.,* 2012). (Beesley, 2010) reported that after the application of biochar complex metals were immobilized and As was mobilized in contaminated soil. (Fellet *et al.,* 2011) reported that addition of biochar in metal contaminated soil to reduce the mobility and bioavailability of Cr, Pb and Cd in soil. Uchimiya *et al.,* (2010) suggested that addition of biochar can enhance soil chemical properties like pH and CEC to increase the complex metal immobilization in polluted soil. (Jiang *et*

al., 2012) conducted an experiment for the immobilization of heavy metals Cu and Pb than Cd by wheat straw derived biochar.

Already most of the results showed that heavy metal mobility and bioavailability decreased due to biochar application in soil under controlled lab conditions, green house experiments and in different small plot trials.

Effect of biochar on bioavailability of heavy metals: Heavy metal bioavailability defines the metal toxicity in soil and has potential risk for human food chain. Pollutant bioavailability enhances the degradation and reduces ecotoxicology in metal contaminated soil. Environmental microbiologists express the bioavailability as a pollutant fraction that shows the convenience of chemical to microbes for absorption and degradation (Naidu *et al.,* 2008).

Park *et al.,* (2011) reported the impact of biochar on artificially spiked and naturally polluted soil. They observed that chicken manure derived biochar effectively decreased concentration of lead and cadmium, but not copper concentration, while using green waste derived biochar was successfully minimizing all the heavy metal from soil. Organic matter contents increased by the application of biochar that was bonded the metals fractions. Both types of biochar reduced cadmium and lead concentration in soil and pore water. Biochar application remediates the toxic metal contaminated soil by preventing heavy metal leaching into water channels and by reducing its availability to plants (Xinde and Harris, 2010).

Biochar derived from wood was applied into metal contaminated soil to examine the biochar impact on availability of arsenic, cadmium, copper, lead, and zinc to maize. Applications of biochar minimized the concentration of arsenic, cadmium, and copper in shoot of maize. However, the effects of Pb and Zn were inconsistent on maize crop by adding biochar (Namgay *et al.,* 2010). Biochar reduced Cd bioavailability by transforming the extractable form of heavy metals to strongly bound form in the soil. (Qiu and Guo, 2010). Stabilization of heavy metals in situ by adding soil amendments like $CaCO_3$ and compost is commonly employed to minimize the metals availability and minimize plant uptake (Bolan and Duraisamy 2003; Bolan *et al.*, 2004).

Biochar can be a good option for metals stabilization in the contaminated soils, and improve the quality of the contaminated soil by significantly reducing the uptake of heavy metals by plants (Ippolito *et al.*, 2012). (Méndez *et al.,* 2012), who suggested that impact of sewage sludge derived biochar on solubility and bioavailability of heavy metals in Mediterranean cultivated lands as compared to without charred sewage sludge. Bioavailability of Zn, Ni, Cd and Pb can be reduced by the amendments of biochar as compared with sewage sludge application. (Zhou *et al.,* 2008) evaluated that application of biochar produced from cotton stalk to cadmium polluted soil and observed the uptake of cadmium by the roots of cabbage. Bioavailability of Cd in contaminated

soil can be mitigated by using cotton stalk derived biochar through sorption and precipitate formation.

(Ahmad et al., 2012), reported that application of mussel shell derived biochar is used to decrease the bioavailability of lead from 75.8 % to 92.5 % and increased soil pH due to biochar amendments as a liming agent. (Karami *et al.,* 2011), observed that application of biochar in Pb and Cu mine polluted soil. They revealed that biochar can reduce the Pb concentrations in pore water of mine polluted soil. Biochar was used with the integration of green waste compost to reduce the level about 20 times as compared to control.

(Houben *et al.*, 2012) investigated the effect of biochar application (1%, 5% and 10%, mass fraction) on different metals uptake by rapeseed (Brassica napus L.). Addition of 10% biochar reduced bioavailability of Cd, Zn and Pb by 71%, 87% and 92% respectively. They suggested that incorporation of biochar into metal-contaminated soils could facilitate to cultivate bioenergy crops without encroaching on agricultural lands and further reduced CO_2 emission.

(Beesley *et al.,* 2013), who conducted a pot experiment to examine the impact of biochar application with and without NPK fertilizer on arsenic (As) availability in soil. Biochar significantly enhanced As concentration in pore water (500ppm–2000ppm) while As concentration in root and shoot concentrations was drastically minimized as compared to the control without biochar. (Cui *et al.,* 2012) applied 0, 10, 20, 40 t ha^{-1} biochar in Pb and Cd contaminated field to investigate soil pH, soil organic carbon and microbial population. The results showed that biochar application significantly reduced the lead and cadmium bioavailability and increased microbial and enzymes activity in soil.

Effect of biochar on adsorption of heavy metals: Sorption capacity of soil can also be improved by the biochar application, due to its impact on the transportation, toxicity and fate behavior of toxic metals in the soil (Glaser *et al.*, 2002 and Lehmann *et al.,* 2002). Biochar have a great potential for heavy metals and their adsorption capacity is compared with other bio sorbents. The adsorption capacity of lead through different biochars ranges from 2.5 from rice husk and 20.6 mg g^{-1} from (bagasse) (Mohan *et al.*, 2007). (Trakal *et al.*, 2011) carried out a batch sorption experiment to examine the effect of single and multi element solution of metal. Application of biochar @ of 1.0% and 2.0% enhanced the sorption behavior of Cu and Pb element as compared to the contaminated and uncontaminated biochar material. The results obtained from these single and comparison with multi element shows different sorption behavior.

Wang *et al.* (2009) studied the batch sorption experiment for the adsorption of Cd (II) ions from aqueous solution by bamboo biochar. The results showed that the adsorption of Cd (II) ions was very fast initially and the equilibrium time was 6 h. The adsorption behavior of Cd (II) ions fitted Langmuir, Temkin and Freundlich isotherms well, but followed

Table 1: Effect of biochar on heavy metal pollution in soil environment.

Feed stock	Temperature	Heavy metals	Reference
Sewage sludge	450-550 ^{0}C	Cd, Cu, Ni, Pb	(Medez et al., 2012)
Green waste of forest	600-800 ^{0}C	Cu	(Buss et al., 2012)
Broiler litter	550-750 ^{0}C	Ni, Cu, Cd	(Uchimiya et al., 2010)
Rice husk	400 ^{0}C	Zn, Cd, As	(Zheng et al., 2012)
Sewage sludge	550 ^{0}C	Sr, Cd, Cr, Pb	Hossain et al., 2010
Pecan shell	450 ^{0}C	Cu	(Uchimiya et al., 2011)
Chicken manure	550 ^{0}C	Pb, Cd, Cu	(Park et al., 2011)
Hard wood	400 ^{0}C	Cu, Pb	(Beesley et al., 2011)
Chicken manure	550 ^{0}C	Pb. Cd	(Park et al., 2013)
Wheat straw	350-550 ^{0}C	Cd	(Cui et al., 2011)
Wheat straw	350-550 ^{0}C	Cd	(Cui et al., 2012)
Orchard waste	500 ^{0}C	Pb, Cr, Cd	(Feelet et al., 2011)
Bamboo	550 ^{0}C	Cd	(Wang et al., 2009)
Dairy manure	350-550 ^{0}C	Cd, As, Pb	(Cao et al., 2009)
Chicken manure	550 ^{0}C	Cd, Pb	(Liu et al., 2009)

Table 2: Effect of biochar on organic contaminants in soil environment .

Feed stock	Temperature	Contaminants (organic)	Reference
Wood chips	800 ^{0}C	Petroleum hydrocarbons	Bushnaf et al., 2011
Rice straw	300-600 ^{0}C	PAHs	Beesley et al., 2010
Sewage Sludge	500 ^{0}C	PAHs	Khan et al., 2012
Soft Wood	450 ^{0}C	PCBs	Denyes et al., 2013
Rice straw	500 ^{0}C	Petroleum	Qin et al., 2013
Red gum wood (eucalyptus)	500 ^{0}C	Azoxystrobin	Sopena et al., 2013
Crop reisdue	450 ^{0}C	Carbaryl	Qiu et al., 2013
Red gum	450-850 ^{0}C	Chlorantraniliprale	Wang et al., 2012
Red gum	450-850 ^{0}C	Chlorpyrifos	Yu et al., 2009
Wood pellet	500 ^{0}C	Aminocyclopyrachlor	Cabrera et al., 2013
Red gum	450-850 ^{0}C	Bentazone	Wang et al., 2012
Red gum wood chips	850 ^{0}C	Chlorantranili	Yu et al., 2010

Langmuir isotherm most precisely, with a maximum adsorption capacity of 12.08 mg/g.

(Ren-kou Xu *et al,*.2013) performed an experiment to investigate the sorption of copper, lead and cadmium by biochar through three variable charged soils from south China. Their findings showed that the incorporation of biochar increased the sorption of copper, lead and cadmium by the soil. (Beesley and Marmiroli 2011) examined the adsorption of Zn, Cd and As on biochar surfaces. They repored that sorption of heavy metals on biochar surface functional groups are not instantly reversible. A dairy manure derived biochar amendments can enhance the sorption of various heavy metals including Pb, As and Cd. Sorption of cadmium is several times more as compared to As (Cao *et al.,* 2009).

By the application of biochar soil pH can be increased that may also increase the sorption of cadmium on biochar surface. Biochar developed surface functional groups such as aromatic OH and carboxylic-C during the oxidation reaction in biochar (Liang *et al.,* 2006). Biochar could also enhance

soil CEC and possibly increase soil exchange capacity for Cd metal (Cheng *et al.,* 2006). Biochar can increase adsorption on acidic variable charged soil integration with other amendments like lime, zeolite and red mud (Gray *et al.,* 2006). Biochar derived from chicken manure was used as organic amendment to enhance the adsorption of heavy metals and reduced their mobility and bioavailability in acidic contaminated soil (Liu *et al.,* 2009).

Biochar has a highest adsorption capacity for heavy metals like copper, lead and cadmium from aqueous solution and from waste water (Tong and Xu 2013). Sorption of heavy metals like copper and lead from soil by the biochar amendments increased with the help of exchange reaction and complexation with metals on functional groups (Jiang *et al.,* 2012).

***Sorption of pesticide*:** Biochar have a efficiency and environmental fate for the sorption of pesticide on its surface area (Kookana *et al.,* 2011). (Spokas *et al.,* 2009) evaluated that the application of biochar would readily sorb aminocyclopyrachlor and also noticeably reduced the

concentration of aminocyclopyrachlor in solution since leaching of herbicides by hardwood biochar has been reduced in Minnesota soils. (Spokas *et al.,* 2009) concluded that amendment of saw dust biochar on a silt loam soil increased sorption of the mobile herbicides atrazine and alachlor. (Cabrera *et al.,* 2011) reported application of six different types of biochar on sandy loam soil having low organic carbon contents. They observed that sorption of mobile pesticide enhanced by the five various biochar out of six and one of them decreased the sorption capacity of pesticide. However, this study was justified by (Yang and Sheng 2003) evaluated that by the application wheat and rice straw derived biochar (ash contents) on silt loam soil to enhanced 2500 times the more sorption of slightly mobile pesticide. (Sheng *et al.,* 2005) also justified pervious study by the application of wheat straw derived biochar enhanced sorption capacity of moderate mobile herbicides bromoxynil and ametryne. Addition of saw dust derived biochar increased 63 times more sorption of mobile terbuthylazine pesticide in volcanic soil.

(Si *et al.,* 2011) investigated the effect of charcoal application in loamy textured soil to enhance the adsorption of mobile isoproturon pesticides and reported positive correlation of adsorption with addition of charcoal into soil.

(Yu *et al.,* 2010) reported that addition of red gum and wood chicp biochar in pesticide contaminanted soil. These biochars have different properties according to their porosity and surface area. Addition of two levels of 1% and 5% biochar on pesticide (pyrimethanil) contaminated soil for increasing its sorption and desorption capacity. This study provides information about the immobilization and mitigation of their environmental effects. The previous study (Yu *et al.,* 2006) proved that the addition of wood derived biochar enhanced sorption of pesticide (diuron), its sorption isotherm and hysteresis noticeably improved with enhancing biochar contents derived from wood in soil.

(James *et al.,* 2005) concluded that addition of wood char derived biochar produced at various temperature increase the sorption of phenanthrene and biochar have heterogeneous surface characteristics to enhance its sorptive ability. (Zheng *et al.,* 2010) reported that application of unmodified biochar on two pesticides atrazine and simazine reduce their environmental fate and decreased their agriculture pollution. The impacts of several biochar properties such as surface area, solution pH, contact time and particle size influenced on pesticides sorption. Pesticide sorption increases by decreasing the solution pH.

Effect of biochar on pesticide bioavailability: Pesticides residues in soil inhibit dehydrogenase activity, while biochar amendments increase enzyme activity and reduced bioavailability of pesticides (Fatima *et al.,* 2013). The study reported the amendment of soil with olive waste feedstock derived biochar to reduce the bioavailability of pesticide (aminocyclopyrachlor) in soil and to prevent the damaging effect on non target plants. Biochar applied (<10% by weight)

to soil for the batch-equilibrium method to measure the pesticides residues concentration in soil (Jennifer *et al.,* 2013).

(Yu *et al.,* 2009) reported that application of two different types of biochar derived from Eucalyptus spp. wood chips pyrolysed at 450 ^{0}C and 850 ^{0}C added @ (0%, 0.1%, 0.5% and 1%) by soil weight to reduce the bioavailability of pesticides. Biochar significantly reduced the pesticide residues with increasing biochar dose in 50 mg kg $^{-1}$ pesticide spiked soil. Biochar produced at 850 ^{0}C have potential to mitigate the phytoavailability of pesticides in soil. (Wang *et al.,* 2012) evaluated that soil amended with biochar decreased the bioavailability of pesticides (chlorantraniliprole) by increasing different physicochemical properties of biochar. Application of biochar produced at 850 ^{0}C decreased the bioavailability of 10 mg kg^{-1} of pesticide residue 0.59 mg kg^{-1} but at 450 ^{0}C residues reduced by 4.02 mg kg^{-1} in soil. (Song *et al.,* 2012) reported that application of wheat straw derived biochar reduced the bioavailability and enhanced the sorption capacity of organic pollutants (hexachlorobenzene) in soil.

Sorption of organic contaminants by biochar: Presence of biochar can increase the organic pollutants sequestration with respect to enhance C sequestration in soil. For example (Chen *et al.,* 2008) reported that pine needle derived biochar produced at various pyrolysis temperature used for the sorption of nitrobenzene, naphthalene, and m-dinitrobenzene. By increasing the pyrolysis temperature the organic carbon contents and surface area were increased and decreased the easter and aliphatic alkyl groups. Correspondingly, the sorption capacity of toluene and benzene were increased on the surface of charcoal produced from red gum at higher temperature (Bornemann *et al.,* 2007) this study was supported by (Chen and Yuan, 2011) evaluated that application of pine needle derived biochar increased sorption capacity on pyrene and naphthalene spiked soil.

Recently (Oleszczuk *et al.,* 2012) showed that by the activated carbon and biochar as an adsorbent amendment in sewage slude matrix consisted of PAHs into pore water. Biochar can mitigate the bioavailability of PAHs from sewage sludge to maintain its essential nutrients status. (Oleszczuk *et al.,* 2012) reported that by the application of activated carbon and biochar increased the diffusion process of PAHs of sewage sludge in pore water through humic functional group layers of adsorbate, reducing free dissolved concentration of PAHs from sewage sludge.

These findings were in lines with (Chai *et al.,* 2012) studied that addition of biochar on furan and dioxin contaminated soils, reduced their uptake by enhancing the contact time and concentration into POM samplers. By increasing pyrolysis temperature of feed stock, biochar had two fractions one is carbonized and other is non- carbonized. Carbonized biochar is used for sorption of non linear aggressive organic pollutants

and other is used for linear non aggressive organic pollutants (Zheng *et al.,* 2010).

(Bushnaf *et al.,* 2011) investigated that impact of biochar (2% on dry weight basis) amendment in hydrocarbon polluted sandy soil. The batch and column study were conducted for remediating the organic polluted soil. This study showed that by the application of biochar in polluted soil, degradation rate of organic petroleum hydrocarbons were controlled by the factor of substrate availability and reduced concentration of other monoaromatic hydrocarbon in soil. (Brandli *et al.,* 2008) reported that biochar and activated carbon is used as strong adsorbant material in soil and sediments for the persistent in-situ remediation of organic hydrocarbon (petroleum) in polluted soil.

(Rhodes *et al.,* 2008) showed that biochar addition as a strong adsorbent on polluted sites for degradation of organic pollutants. Biochar used as carbonaceous material for the sorption of organic pollutants from polluted soil reduced their bio-uptake by plants. The transfer rate of pollutants from soil to food chain can be reduced by the application of biochar and activated carbon in soil. Pollutants bioavailabilities reduced for microbial breakdown and enhanced their persistence (Rhodes *et al.,* 2008). (Khan *et al.,* 2013) investigated the influence of sewge sludge 2% and sewage sludge derived biochar (2, 5 and 10%) applied respectively to multi contaminated soil. Both sewage sludge biochar and sewage sludge amendments increased lettuce biomass and significantly 56% to 67% reduced bioaccumulation of PAHs from soil.

(Wang *et al.,* 2011) reported that application of biochar significantly reduced the mobility of heavy metals and enhanced sorption ability of strongly hydrophobic hydrocarbons. (Denyes *et al.,* 2013) reported the in situ application of activated carbon and biochar for mitigating the PCBs bioavailability and bioaccumulation in polluted soil. (Qin *et al.,* 2013) studied that application of rice straw biochar on petroleum-contaminated soil. Biochar increased its sorption of large amount of metabolites and also reduced their toxicity and enhanced biodegradation rate. (Song *et al.,* 2012) studied the influence of wheat straw biochar applied 0.1% application rate to increase sorption of POPs and reduced their bioavailability in contaminated soils.

Conclusion: This paper reviews the remediation of organic and inorganic pollutant of soil through manipulating their bioavailability using several types of biochar, have supporting the concept of "designer biochar". Biochar has potential to sorb these organic and inorganic pollutants from soil by its effective physical and chemical properties to reduce the transfer of these pollutants from soil to food chain. In fact, laboratory studies have provided useful date about biochar and its ash impact as immobilizing agent for heavy metal, organic and hydrocarbons pollutants. Several studies are required to highlight the biochar efficiency for such type of pollutants in field levels, and these studies should be for long

time. Moreover, biochar as amendments with other organic and inorganic agents are useful as immobilizing influence on physiological process of plants, such as (photosynthetic activity, hydrolysis, plant nutrient uptake, tropism, plant growth hormones and their functions, plant response to environmental stress, osmotic pressure, turgor potential and stomata function in relation to plant-water nexus. Further studies are required on the chelate-assisted phytoremediation and the root-soil interface.

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